EXHIBIT A

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Gas lift

Sci-Tech Dictionary: **gas lift**

('gas 'lift)

(*chemical engineering*) Solids movement operation in which an upward-flowing gas stream in a closed conduit or vessel is used to lift and move powdered or granular solid material.
(*petroleum engineering*) The injection of gas near the bottom of an oil well to aerate and lighten the column of oil to increase oil production from the well.

Related Videos: **Gas lift**

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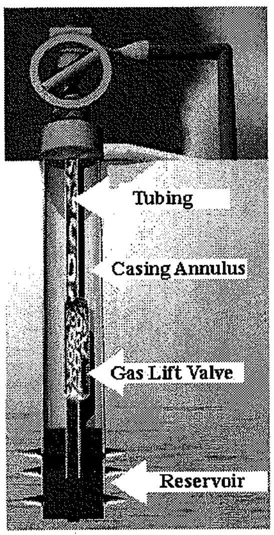
Gas lift is one of a number of processes used to artificially lift oil or water from wells where there is insufficient reservoir pressure to produce the well. The process involves injecting gas through the tubing-casing annulus. Injected gas aerates the fluid to reduce its density; the formation pressure is then able to lift the oil column and forces the fluid out of the wellbore. Gas may be injected continuously or intermittently, depending on the producing characteristics of the well and the arrangement of the gas-lift equipment.



Gas lift is a form of artificial lift where gas bubbles lift the oil from the well.

The amount of gas to be injected to maximize oil production varies based on well conditions and geometries. Too much or too little injected gas will result in less than maximum production. Generally, the optimal amount of injected gas is determined by well tests, where the rate of injection is varied and liquid production (oil and perhaps water) is measured.

Although the gas is recovered from the oil at a later separation stage, the process requires energy to drive a compressor in order to raise the pressure of the gas to a level where it can be re-injected.

The gas-lift mandrel is a device installed in the tubing string of a gas-lift well onto which or into which a gas-lift valve is fitted. There are two common types of mandrels. In a conventional gas-lift mandrel, a gas-lift valve is installed as the tubing is placed in the well. Thus, to replace or repair the valve, the tubing string must be pulled. In the side-pocket mandrel, however, the valve is installed and removed by wireline while the mandrel is still in the well, eliminating the need to pull the tubing to repair or replace the valve.

A gas-lift valve is a device installed on (or in) a gas-lift mandrel, which in turn is put on the production tubing of a gas-lift well. Tubing and casing pressures cause the valve to open and close, thus allowing gas to be injected into the fluid in the tubing to cause the fluid to rise to the surface. In the lexicon of the industry, gas-lift mandrels are said to be "tubing retrievable" wherein they are deployed and retrieved attached to the production tubing. See gas-lift mandrel.

Examples of typical gas-lift valves and mandrels may be found at: http://www.tejasre.com/Products_Gas_Lift_Home.cfm

Other typical examples of equipment also used in connection with gas-lift production may be found at: http://www.bstlift.com

See also

- Pumpjack
- Progressive cavity pump
- Submersible pump

v·d·e

Petroleum industry [hide]

Exploration	Petroleum engineering (Reservoir simulation · Seismic to simulation) · Petroleum geology · Geophysics · Seismic (Seismic inversion) · Petrophysics · Core sampling
Drilling	Drilling engineering · Underbalanced drilling · Directional drilling · (Measurement while drilling · Geosteering) · Drilling fluid · Drill Stem Test
Development	Completion (Squeeze job) · Well logging · Pipeline transport · Tracers
Production	Artificial lift (Pumpjack · ESP · **Gas lift**) · EOR (Steam injection · Gas reinjection) · Water injection · Well intervention · Upstream · Midstream · Downstream · Refining
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EXHIBIT B

Gas-Lift

Benefits of Detailed Compressor Modelling in Optimising Production from Gas-Lifted Fields

MANICKAM S. NADAR, PRINCIPAL PETROLEUM ENGINEER, AND CALUM MCKIE, M.E. REGIONAL MANAGER, EDINBURGH PETROLEUM SERVICES

THE IMPORTANCE OF COMPRESSOR PERFORMANCE IN GAS-LIFT OPTIMISATION

Gas-lift is one of the major artificial lift methods employed for oil production. In implementations where there is no external source of high pressure lift-gas (eg, a gas field nearby), compressors are used to provide the lift-gas supply by recycling the low pressure associated gas produced with the oil. Figure1. shows a schematic of a typical gas-lifted production system. Lift-gas leaving the discharge side of the compressors travels through a distribution network to the individual wells, and returns to the production separators along with the fluids (oil, gas and water) produced from the reservoir. The gas is separated from the liquids, and passes to the compressors and from there back to the wells.

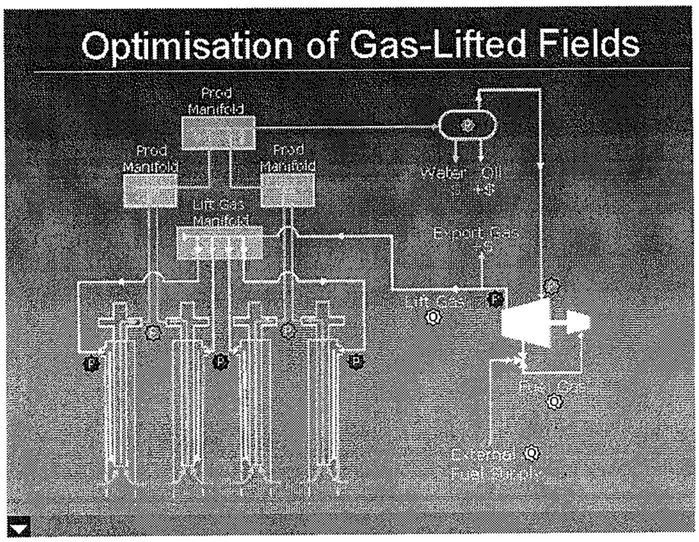

Figure 1

Traditional optimisation methods have focused on the combined performance of the production side of the system: ie, the wells and the pipe network that carries the produced fluids to the separators. However in order to fully optimise the total system, it is necessary to also consider the lift-gas side, including the compressors.

The most important behaviour characteristic for compressors with regards to total system optimisation is that the power required to drive the compressor increases with flowrate and pressure rise. Therefore for a given amount of power available, increasing the flowrate reduces the pressure rise that can be achieved, and vice-versa. This leads to the following dependencies with other parts of the system:

- Compressor flowrate controls the total lift-gas available. For each well, there will be an optimal lift-gas rate which maximises its production rate or net revenue contribution at the prevailing conditions. Ideally, the total lift-gas available should be equal to the sum of the optimal lift-gas rates to all of the wells. If it is lower than this, the lift-gas rate allocated to some of the wells will need to be lower than the optimum.
- Compressor suction pressure controls the minimum allowable separator pressure. In general, there is a trade-off between lowering the separator pressure to reduce wellhead pressures and increase well deliverability, and reducing the total lift-gas available due to the increased pressure rise.
- Compressor discharge pressure controls the maximum lift-gas pressure available at the individual wells. This in turn controls the maximum lift-gas rate into the well, and also the maximum depth at which the gas can enter the tubing to reduce the density of the fluid column: in general, this should be as deep as possible. There is therefore a trade-off between maintaining a compressor discharge pressure which is sufficiently high to provide the desired lift-gas pressure at the wells, and the effect of the increased pressure rise on the total lift-gas available.

Most large-scale implementations of gas-lift use centrifugal compressors, and these are further constrained by the surge and stonewall aerodynamic limits (see Figure 2). The compressor cannot be operated to the left of the surge line, or to the right of the stonewall line.

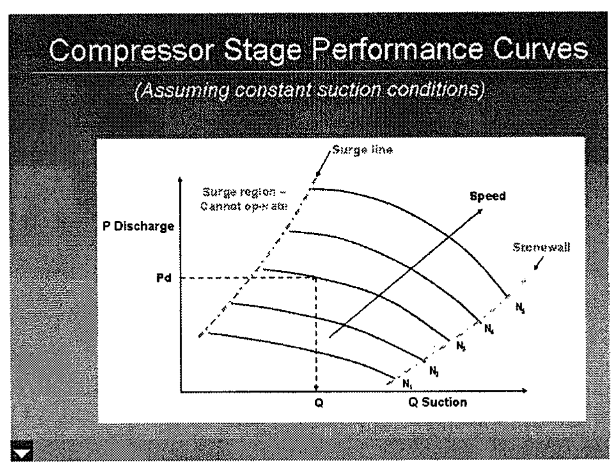

Figure 2

If gas turbines are used to drive the compressors, then the power available cannot be assumed to be constant. The power available from a gas turbine is dependent upon ambient temperature, and in a region such as the Gulf where there is a large seasonal fluctuation in air

temperature, the power available in the summer can be 15 per cent lower than in the winter. The power available may also reduce between overhauls.

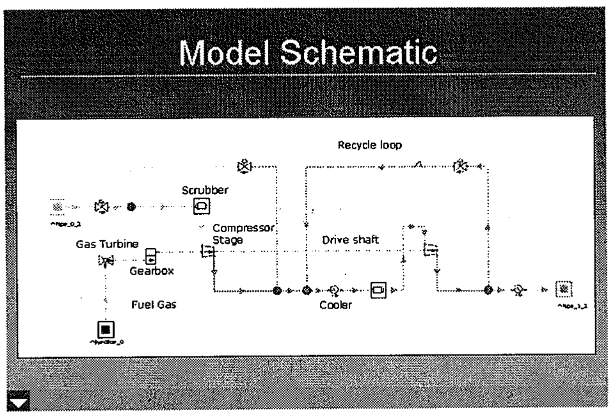

Figure 3

THE DETAILED COMPRESSOR MODEL

ReO, the Resource Optimiser software from Edinburgh Petroleum Services Ltd, has the ability to optimise large and complex gas-lifted fields, while taking into account the interactions between the various elements of the total system. The detailed compressor model incorporated in this software has the ability to represent the key features of compressor performance described previously. A schematic of a detailed compressor model in ReO is shown in Figure 3. The engineer is able to construct a model representing the configuration of his particular multi-stage compressor system, using objects such as gas turbines, compressor stages, inter-stage coolers and scrubbers, and control valves.

The gas turbine object contains a performance map which defines the maximum power available as a function of power turbine speed, and also the variation of efficiency with operating conditions, allowing the calculation of fuel-gas consumption. A correction can be applied to the performance map to account for changes in ambient temperature. The compressor stage object contains the performance map shown in Figure 2; it is expressed in dimensionless form, allowing the complete performance surface to be represented by just two curves.

BENEFITS OF DETAILED COMPRESSOR MODELLING

Applications of ReO's compressor model to gas-lifted fields worldwide have shown the following benefits:

• Separator pressures have been lowered, resulting in increased production. The model allows the optimum separator pressure to be quickly calculated for current field conditions. Without such a model, the calculation is complex and time-consuming, and is therefore performed infrequently, if at all. In addition, field production staff are rightly concerned about minimising downtime, and may be tempted to set the separator pressure higher than strictly necessary, to avoid trips.

• Discharge pressures have been lowered, increasing total lift-gas availability. The model allows direct calculation of the discharge pressure which gives the best compromise between the minimum pressure required at the wells and compressor throughput. Once again, in the absence of such a model the calculation is complex and time-consuming, and is therefore rarely performed.

• Compressor operating costs have been reduced and availability has been increased. In some cases, the optimiser has recommended that whole compressor trains are surplus to requirements, allowing them to be shut down. This results in reduced maintenance costs and increased availability since the stopped machine becomes reserve capacity. Even where a train cannot be shut down, it may be possible to run it at a lower percentage of rated power, which increases the run-life between overhauls.

Interestingly, although there appears to be potential for saving operating costs by reducing fuel gas consumption if compressor power is reduced, experience suggests that the savings are negligible, even in cases where the fuel gas is purchased from an external source such as a utility. The main reason for this is that the variation in a gas turbine's fuel consumption with power output is too small to play a significant part in the optimisation.

• The model results in a superior shared understanding of total system behaviour between staff from the various engineering disciplines involved in field operations, particularly petroleum engineers and compressor operating and maintenance staff.

In conclusion, gas-lifting remains an important technique to enhance the production of mature oil fields. In many fields the current practice is to optimise individual wells, or occasionally to include the production gathering network in the optimisation process. Recent developments such as EPS's ReO software allow a more holistic approach to be taken, enabling the optimisation of the total system including the compressors. This approach delivers increased net revenue, and also provides operational benefits ■

This paper was first presented at the 2nd Middle East Artificial Lift Forum held in Dubai on 1 & 2 June 2004

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EXHIBIT C

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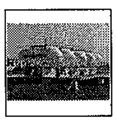

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EXHIBIT D

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Paper Number 16691-MS

DOI What's this? 10.4043/16691-MS

Title **GOM Export Gas Pipeline, Hydrate Plug Detection and Removal**

Authors Sam Kashou, ChevronTexaco Energy Technology Company, Sivakumar Subramanian, ChevronTexaco Energy Technology Company, Patrick Matthews, ChevronTexaco Energy Technology Company, Lawrence Thummel, Williams Field Services Company, Eric Faucheaux, Williams Field Services Company, Daniel Subik, Deepwater Business Unit-ChevronTexaco North America Upstream, David Qualls, Deepwater Business Unit-ChevronTexaco North America Upstream, Rollin Akey, Deepwater Business Unit-ChevronTexaco North America Upstream, Jerry Carter, Deepwater Business Unit-ChevronTexaco North America Upstream

Source Offshore Technology Conference, 3 May-6 May 2004, Houston, Texas

Language English

Preview

Abstract
Hydrate blockage detection, remediation and removal are successfully applied in a hydrate plug incident in the GOM. A hydrate plug occurred in mid-October 2002 in the Williams Field Services (WFS) owned and operated, 36-mile long, 10-inch gas export pipeline from ChevronTexaco's Genesis Green Canyon 205 (GC 205) platform (2,600 ft water depth) to the downstream Ship Shoal 354 platform (SS 354) platform (460 ft water depth). ChevronTexaco's Flow Assurance experts, ChevronTexaco's Genesis Asset Team, and WFS team worked together to detect, locate and remediate the hydrate plug in a safe and timely fashion while ensuring personnel safety, maintaining pipeline and riser integrity and minimizing loss of production. This paper shows how a concentrated team effort and deployment of the right tools such as transient models, hydrate formation and dissociation models, can be used to predict and alleviate a flow assurance problem, such as hydrates, which can occur in deepwater oil and gas production in a subsea system.

Introduction
The Genesis development[1] was brought on stream in February 1, 1999. In mid-October 2002, following two major shutdowns due to strong hurricanes and one for WFS planned maintenance, gas flow into the dry gas export pipeline to SS 354 was obstructed and gas delivery to shore was halted. Analysis of the measured hydraulic data prior to and during the incident showed that the obstruction in the gas pipeline was due to the presence of hydrates corresponding to low spots in the pipeline. Operations personnel in New Orleans, working in conjunction with Flow Assurance personnel in Houston were able to locate the hydrate plug via hydraulic and hydrate models based on the measured pressure, temperature and gas flow rate during the incident. Hydrate formation caused by the presence of water and natural gas components at high pressures and low temperatures in a deep-water subsea pipeline can occur during shutdown or start-up of a pipeline as was the case with Genesis. Under normal flowing conditions, dehydrated gas flows through the uninsulated Genesis export gas pipeline. Although pressures in the line were high (~1,600 psig at inlet) and temperatures as low as 42 °F in the coldest sections of the pipeline, hydrate formation was not expected due to the low water content of gas from dehydration at GC 205. However, in the presence of sufficient water, pressures and temperatures of the flowing stream in the pipeline were conducive to hydrate formation. Since water content of gas entering the pipeline was routinely monitored below hydrate formation content while flowing, hydrates should not have formed in the pipeline during steady state flow.
When hydrates did form in the pipeline, many factors may have contributed to that formation such as the multiple shutdowns within a few days of each other and the added complexity in the procedures of shutting the platform down and starting it back up. During these back to back platform shut downs and start-ups, if any water had entered into the pipeline due to non-optimal dehydrator performance, the potential for hydrate formation would have been be high.

Overview
Genesis is ChevronTexaco's first deepwater oil and natural gas drilling and production facility located in 2,600 ft of water in the Gulf of Mexico, 150 miles south of New Orleans. The field is operated by ChevronTexaco with 56.67% working interest, and partner ExxonMobil with 38.38% working interest and PetroFina Delaware, Incorporated, with 4.95% working interest.

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EXHIBIT E

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Renewable energy

US History Encyclopedia:

Renewable Energy

Wood, wind, water, and sun power have been used for cooking, heating, milling, and other tasks for millennia. During the Industrial Revolution of the eighteenth and early nineteenth centuries, these forms of renewable energy were replaced by fossil fuels such as coal and petroleum. At various times throughout the nineteenth and twentieth centuries, people believed that fossil fuel reserves would be exhausted and focused their attentions on sources of renewable energy. This led to experiments with solar steam for industry and solid wood, methanol gas, or liquid biofuels for engines. Attention has refocused on renewable energy sources since the 1960s and 1970s, not only because of concern over fossil fuel depletion, but also because of apprehension over acid rain and global warming from the accumulation of carbon dioxide in the atmosphere.

Acid rain is clearly the result of the use of fossil fuels, and most authoritative climatologists also believe that these fuels are contributing to global warming. Many scientists and environmentalists have, therefore, urged a global switch to renewable energy, which derives from the sun or from processes set in motion by the sun. These energy forms include direct use of solar power along with windmills, hydroelectric dams, ocean thermal energy systems, and biomass (solid wood, methane gas, or liquid fuels). Renewable energy thus differs not only from fossil energy sources such as petroleum, gas, and coal, but also from nuclear energy, which usually involves dividing uranium atoms.

In the early 1990s, one-fifth of worldwide energy use was renewable, with by far the largest portion of this coming from fuel wood and biomass. Hydroelectric dams made up most of the rest. More than half the world's population relied on wood for cooking and heating, and although wood is generally considered to be renewable, excessive reliance has long been recognized as a cause of deforestation. Forests disappear faster than they can be renewed by natural processes. Energy "crops" —for example, fast-growing acacia or eucalyptus trees planted for fuel wood in the Third World—and more efficient wood stoves may be useful to poor, wood-reliant nations.

Solar energy is a term for many techniques and systems. The sun's energy can be trapped under glass in a greenhouse or within solar panels that heat water. It can also be concentrated in a trough or parabolic collector. In arid climates a small version of a concentrator is sometimes used to substitute for wood. Although economical, it is unreliable, hard to transport, and difficult to operate. Larger concentrators can produce steam economically for industry or for electric utilities in some climates. Another form of solar energy comes from photovoltaic cells mounted on panels. These panels are economical for all kinds of remote power needs, from cheap hand calculators to mountaintop navigational beacons to orbiting satellites. Costs have dropped dramatically since the mid-1970s, from hundreds of thousands of

dollars to several thousands per installed kilowatt, and are expected to drop to under a thousand dollars early in the twenty-first century. At some point they may become competitive with nuclear and fossil energy.

Water power has been well known since its use in the Egyptian and classical Greek civilizations, and at the outset of the Industrial Revolution, it was widely used in Europe and the Americas to grind grain and run looms and in other small-scale industrial processes. Today water power is by far the cheapest of all fossil, nuclear, and renewable forms of energy for producing electricity, but the ecological disruptions caused by hydroelectric dams have caused many environmental controversies. Ocean energy takes advantage of the movement of water in tides or waves or of the temperature difference between sun-heated surface water and cold deep water. A few tidal energy projects have been built, but this form of energy production is expensive and remains largely experimental. Like tidal energy, geothermal energy is produced by continuous natural processes not directly related to solar cycles. Geo-thermal energy takes advantage of hot water trapped deep inside the earth to produce electricity or heat for homes and industry.

Wind power has been used for grinding grain, pumping water, and powering sawmills since the Middle Ages, and thousands of windmills once dotted coastal areas of northern Europe. Water-pumping windmills were a fixture in the American Midwest well into the twentieth century. Windmills are returning in a high-tech form in places like Altamont Pass in California, where they produce electricity. They are widely used for pumping water in the Third World.

Biomass energy involves a wide range of low and high technologies, from wood burning to use of manure, sea kelp, and farm crops to make gas and liquid biofuels. Brazil leads the world in use of pure ethyl alcohol derived from sugarcane as a replacement for petroleum. A common fuel in the United States is corn-derived ethyl alcohol, which is used as a low-pollution octane booster in a 10-percent blend with gasoline called "gasohol." Another form of renewable energy used in the rural Third World is the gas-producing biogas digester. Human and animal wastes are mixed with straw and water in an airless underground tank made of brick or cement. Methane gas is siphoned from the tank to a cooking stove. Meanwhile, the tank gets hot enough to kill disease-causing bacteria, which is an important sanitary improvement in many countries. Over the past few decades, 5 million biogas tanks have been built in China and half a million in India.

Renewable energy resources are cleaner and far more abundant than fossil resources, but they tend to be dispersed and more expensive to collect. Many of them, such as wind and solar energy, are intermittent in nature, making energy storage or distributed production systems necessary. Therefore, the direct cost of renewable energy is generally higher than the direct cost of fossil fuels. At the same time, fossil fuels have significant indirect or external costs, such as pollution, acid rain, and global

warming. How to account for these external costs and assign the savings to renewable energy is a matter of continued policy debate. Another policy issue is research and development support. Conventional forms of energy, such as fossil fuels and nuclear power, receive more financial support from the federal government than does renewable energy. U.S. government policy toward renewable energy has been a roller coaster of support and neglect. By the end of President Jimmy Carter's administration in 1981, federal contributions to research in solar photovoltaics, solar thermal energy, solar buildings, biofuels, and wind energy research had soared to almost $500 million, but by 1990 the figure was only $65 million. A global transition to renewable energy will have to include developing nations, where energy use in proportion to the world total grew from 20 percent in 1970 to 3l percent in 1990.

Bibliography

Berinstein, Paula. *Alternative Energy: Facts, Statistics, and Issues.* Westport, Conn.: Oryx Press, 2001.

Blackburn, John O. *The Renewable Energy Alternative: How the United States and the World Can Prosper Without Nuclear Energy or Coal.* Durham, N.C.: Duke University Press, 1987.

Butti, Ken, and John Perlin. *A Golden Thread: 2,500 Years of Solar Architecture and Technology.* New York: Van Nostrand Reinhold, 1980.

Flavin, Christopher. *Beyond the Petroleum Age: Designing a Solar Economy.* Washington, D.C.: Worldwatch Institute, 1990.

Kovarik, Bill. *Fuel Alcohol: Energy and Environment in a Hungry World.* London: International Institute for Environment and Development, 1982.

Sørensen, Bent. *Renewable Energy: Its Physics, Engineering, Use, Environmental Impact, Economy and Planning Aspects.* San Diego, Calif.: Academic Press, 2000.

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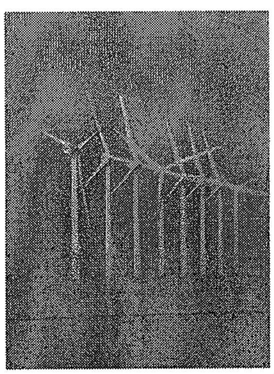
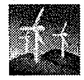


Burbo Bank Offshore Wind Farm, at the entrance to the River Mersey in North West England.

American President Barack Obama speaks at the DeSoto Next Generation Solar Energy Center, in

the USA.

Renewable energy



Biofuel
Biomass
Geothermal
Hydroelectricity
Solar energy
Tidal power
Wave power
Wind power

v • d • e

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In 2008, about 19% of global final energy consumption came from renewables, with 13% coming from traditional biomass, which is mainly used for heating, and 3.2% from hydroelectricity.[1] New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 2.7% and are growing very rapidly.[1] The share of renewables in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewables.[1][2]

Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 157,900 megawatts (MW) in 2009,[3][4] and is widely used in Europe, Asia, and the United States.[5] At the end of 2009, cumulative global photovoltaic (PV) installations surpassed 21,000 MW[6][7][8] and PV power stations are popular in Germany and Spain.[9] Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert.[10] The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel.[11] Ethanol fuel is also widely available in the USA.

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development.[12] Globally, an estimated 3 million households get power from small solar PV systems. Micro-hydro systems configured into village-scale or county-scale mini-grids serve many areas.[13] More than 30 million rural households get lighting and cooking from biogas made in household-scale digesters. Biomass cookstoves are used by 160 million households.[13]

Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization.[14] New government spending, regulation and policies helped the industry weather the 2009 economic crisis better than many other sectors.[15]

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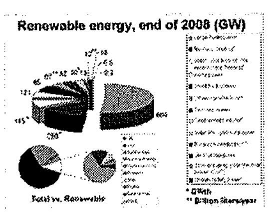
Overview



2008 worldwide renewable-energy sources. *Source: REN21*[16]

Renewable energy flows involve natural phenomena such as sunlight, wind, tides and geothermal heat, as the International Energy Agency explains:[17]

> Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Renewable energy replaces conventional fuels in four distinct

areas: power generation, hot water/ space heating, transport fuels, and rural (off-grid) energy services:[18]

- **Power generation**. Renewable energy provides 18 percent of total electricity generation worldwide. Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas: for example, 14 percent in the U.S. state of Iowa, 40 percent in the northern German state of Schleswig-Holstein, and 20 percent in Denmark. Some countries get most of their power from renewables, including Iceland (100 percent), Brazil (85 percent), Austria (62 percent), New Zealand (65 percent), and Sweden (54 percent).[19]
- **Heating**. Solar hot water makes an important contribution in many countries, most notably in China, which now has 70 percent of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly.[19]
- **Transport fuels**. Renewable biofuels have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced the equivalent of an estimated 68 billion liters of gasoline, equal to about 5 percent of world gasoline production.[19]

Mainstream forms of renewable energy

Wind power

See also: Wind power, Wind farm, and Wind power in the United States

Airflows can be used to run wind turbines. Modern wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use; the power output of a turbine is a function of the cube of the wind speed, so as wind speed increases, power output increases dramatically.[20] Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms. Typical capacity factors are 20-40%, with values at the upper end of the range in particularly favourable sites.[21][22]

Globally, the long-term technical potential of wind energy is believed to be five times total current global energy production, or 40 times current electricity demand. This could require large amounts of land to be used for wind turbines, particularly in areas of higher wind resources. Offshore resources experience mean wind speeds of ~90% greater than that of land, so offshore

resources could contribute substantially more energy.[23]

Wind power is renewable and produces no greenhouse gases during operation, such as carbon dioxide and methane.

Hydropower

See also: Hydroelectricity and Hydropower

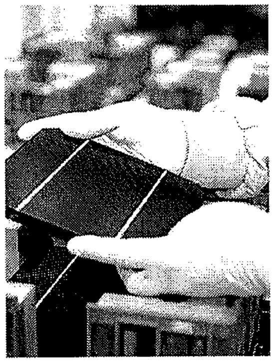
The Hoover Dam when completed in 1936 was both the world's largest electric-power generating station and the world's largest concrete structure.

Energy in water can be harnessed and used. Since water is about 800 times denser than air,[24][25] even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy. There are many forms of water energy:

- Hydroelectric energy is a term usually reserved for large-scale hydroelectric dams. Examples are the Grand Coulee Dam in Washington State and the Akosombo Dam in Ghana.
- Micro hydro systems are hydroelectric power installations that typically produce up to 100 kW of power. They are often used in water rich areas as a remote-area power supply (RAPS). There are many of these installations around the world, including several delivering around 50 kW in the Solomon Islands.
- Damless hydro systems derive kinetic energy from rivers and oceans without using a dam.
- Ocean energy describes all the technologies to harness energy from the ocean and the sea. This includes marine current power, ocean thermal energy conversion, and tidal power.

Solar energy

See also: Solar energy, Solar power, and Solar thermal energy



Monocrystalline solar cell.

Solar energy is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaics and heat engines. A partial list of other solar applications includes space heating and cooling through solar architecture, daylighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes.

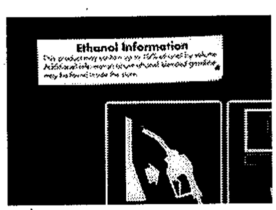
Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

Biomass

Biomass (plant material) is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, plants capture the sun's energy. When the plants are burned, they release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy. As long as biomass is produced sustainably, with only as much used as is grown, the battery will last indefinitely.[26]

In general there are two main approaches to using plants for energy production: growing plants specifically for energy use, and using the residues from plants that are used for other things. The best approaches vary from region to region according to climate, soils and geography.[26]

Biofuel



Information on pump regarding

ethanol fuel blend
up to 10%,
California.

Liquid biofuel is usually either bioalcohol such as bioethanol or an oil such as biodiesel.

Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil.

Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

Biofuels provided 1.8% of the world's transport fuel in 2008.[27]

Geothermal energy

Main articles: Geothermal energy, Geothermal heat pump, and Renewable energy in Iceland

Krafla Geothermal Station in northeast Iceland

Geothermal energy is energy obtained by tapping the heat of the earth itself, both from kilometers deep into the Earth's crust in some places of the globe or from some meters in geothermal heat pump in all the places of the planet . It is expensive to build a power station but operating costs are low resulting in low energy costs for suitable sites. Ultimately, this energy derives from heat in the Earth's core.

Three types of power plants are used to generate power from geothermal energy: dry steam, flash, and binary. Dry steam plants take steam out of fractures in the ground and use it to directly drive a turbine that spins a generator. Flash plants take hot water, usually at temperatures over 200 °C, out of the ground, and allows it to boil as it rises to the surface then separates the steam phase in steam/water separators and then runs the steam through a turbine. In binary plants, the hot water flows through heat exchangers, boiling an organic fluid that spins the turbine. The condensed steam and remaining geothermal fluid from all three types of plants are injected back into the hot rock

to pick up more heat.[citation needed]

The geothermal energy from the core of the Earth is closer to the surface in some areas than in others. Where hot underground steam or water can be tapped and brought to the surface it may be used to generate electricity. Such geothermal power sources exist in certain geologically unstable parts of the world such as Chile, Iceland, New Zealand, United States, the Philippines and Italy. The two most prominent areas for this in the United States are in the Yellowstone basin and in northern California. Iceland produced 170 MW geothermal power and heated 86% of all houses in the year 2000 through geothermal energy. Some 8000 MW of capacity is operational in total.[citation needed]

There is also the potential to generate geothermal energy from hot dry rocks. Holes at least 3 km deep are drilled into the earth. Some of these holes pump water into the earth, while other holes pump hot water out. The heat resource consists of hot underground radiogenic granite rocks, which heat up when there is enough sediment between the rock and the earths surface. Several companies in Australia are exploring this technology. [citation needed]

Renewable energy commercialization

Main article: Renewable energy commercialization

Growth of renewables

During the five-years from the end of 2004 through 2009, worldwide renewable energy capacity grew at rates of 10–60 percent annually for many technologies. For wind power and many other renewable technologies, growth accelerated in 2009 relative to the previous four years.[18] More wind power capacity was added during 2009 than any other renewable technology. However, grid-connected PV increased the fastest of all renewables technologies, with a 60-percent annual average growth rate for the five-year period.[18]

Selected renewable energy indicators[28][29][30]

Selected global indicators	2007	2008	2009
Investment in new renewable capacity (annual)	104	130	150 billion USD
Existing renewables power capacity, including large-scale hydro	1,070	1,140	1,230 GWe
Existing renewables power capacity, excluding large hydro	240	280	305 GWe
Wind power capacity (existing)	94	121	159 GWe
Solar PV capacity (grid-connected)	7.6	13.5	21 GWe
Solar hot water capacity	126	149	180 GWth
Ethanol production (annual)	50	69	76 billion liters
Biodiesel production (annual)	10	15	17 billion liters
Countries with policy targets for	68	75	85

renewable energy use

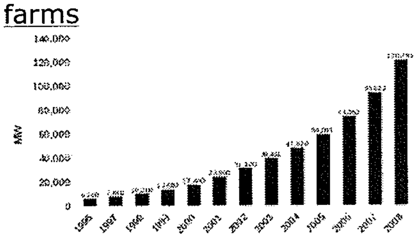
Economic trends

All forms of energy are expensive, but as time progresses, renewable energy generally gets cheaper,[31][32] while fossil fuels generally get more expensive. Al Gore has explained that renewable energy technologies are declining in price for three main reasons:[33]

> First, once the renewable infrastructure is built, the fuel is free forever. Unlike carbon-based fuels, the wind and the sun and the earth itself provide fuel that is free, in amounts that are effectively limitless.
>
> Second, while fossil fuel technologies are more mature, renewable energy technologies are being rapidly improved. So innovation and ingenuity give us the ability to constantly increase the efficiency of renewable energy and continually reduce its cost.
>
> Third, once the world makes a clear commitment to shifting toward renewable energy, the volume of production will itself sharply reduce the cost of each windmill and each solar panel, while adding yet more incentives for additional research and development to further speed up the innovation process.[33]

Wind power market

See also: List of onshore wind farms and List of offshore wind farms

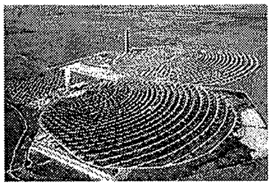


Wind power: worldwide installed capacity 1996-2008

At the end of 2009, worldwide wind farm capacity was 157,900 MW, representing an increase of 31 percent during the year,[3] and wind power supplied some 1.3% of global electricity consumption.[34] Wind power accounts for approximately 19% of electricity use in Denmark, 9% in Spain and Portugal, and 6% in Germany and the Republic of Ireland.[35] The United States is an important growth area and installed U.S. wind power capacity reached 25,170 MW at the end of 2008.[36] As of September 2009, the Roscoe Wind Farm (781 MW) is the world's largest wind farm.[37]

As of 2009, the 209 megawatt (MW) Horns Rev 2 wind farm in Denmark is the world's largest offshore wind farm. The United Kingdom is the world's leading generator of offshore wind power, followed by Denmark.[38]

New generation of solar thermal plants



Solar Towers from left: PS10, PS20.

Main article: List of solar thermal power stations
See also: Solar power plants in the Mojave Desert

Large solar thermal power stations include the 354 MW Solar Energy Generating Systems power plant in the USA, Nevada Solar One (USA, 64 MW), Andasol 1 (Spain, 50 MW), Andasol 2 (Spain, 50 MW), PS20 solar power tower (Spain, 20 MW), and the PS10 solar power tower (Spain, 11 MW).

The solar thermal power industry is growing rapidly with 1.2 GW under construction as of April 2009 and another 13.9 GW announced globally through 2014. Spain is the epicenter of solar thermal power development with 22 projects for 1,037 MW under construction, all of which are projected to come online by the end of 2010.[39] In the United States, 5,600 MW of solar thermal power projects have been announced.[40] In developing countries, three World Bank projects for integrated solar thermal/combined-cycle gas-turbine power plants in Egypt, Mexico, and Morocco have been approved.[41]

Photovoltaic market

Main article: List of photovoltaic power stations

40 MW PV Array installed in Waldpolenz, Germany

Photovoltaic production has been increasing by an average of some 20 percent each year since 2002, making it a fast-growing energy technology.[42][6] At the end of 2009, the cumulative global PV installations surpassed 21,000 megawatts.[6][7]

As of October 2009, the largest photovoltaic (PV) power plants in the world are the Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura photovoltaic power station (Portugal, 46 MW), and the Waldpolenz Solar Park (Germany, 40 MW).[43]

Many of these plants are integrated with agriculture and some use innovative tracking systems that follow the sun's daily path across the sky to generate more electricity than conventional fixed-mounted systems. There are no fuel costs or emissions during operation of the power stations.

Topaz Solar Farm is a proposed 550 MW solar photovoltaic power plant which is to be built northwest of California Valley in the USA at a cost of over $1 billion.[44] High Plains Ranch is a proposed 250 MW solar photovoltaic power plant which is to be built on the Carrizo Plain, northwest of California Valley.[45]

However, when it comes to renewable energy systems and PV, it is not just large systems that matter. Building-integrated photovoltaics or "onsite" PV systems have the advantage of being matched to end use energy needs in terms of scale. So the energy is supplied close to where it is needed.[46]

Use of ethanol for transportation

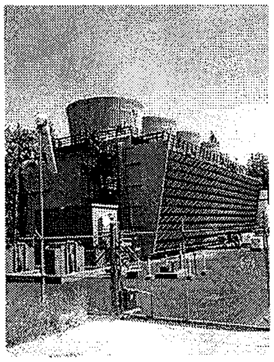
E95 trial bus operating in São Paulo, Brazil.

See also: Ethanol fuel and BioEthanol for Sustainable Transport

Since the 1970s, Brazil has had an ethanol fuel program which has allowed the country to become the world's second largest producer of ethanol (after the United States) and the world's largest exporter.[47] Brazil's ethanol fuel program uses modern equipment and cheap sugar cane as feedstock, and the residual cane-waste (bagasse) is used to process heat and power.[48] There are no longer light vehicles in Brazil running on pure gasoline. By the end of 2008 there were 35,000 filling stations throughout Brazil with at least one ethanol pump.[49]

Nearly all the gasoline sold in the United States today is mixed with 10 percent ethanol, a mix known as E10,[50] and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Ford, DaimlerChrysler, and GM are among the automobile companies that sell "flexible-fuel" cars, trucks, and minivans that can use gasoline and ethanol blends ranging from pure gasoline up to 85% ethanol (E85). By mid-2006, there were approximately six million E85-compatible vehicles on U.S. roads.[51] The challenge is to expand the market for biofuels beyond the farm states where they have been most popular to date. Flex-fuel vehicles are assisting in this transition because they allow drivers to choose different fuels based on price and availability. The *Energy Policy Act of 2005*, which calls for 7.5 billion gallons of biofuels to be used annually by 2012, will also help to expand the market.[51]

Geothermal energy commercialization



The West Ford Flat power plant is one of 21 power plants at The Geysers.

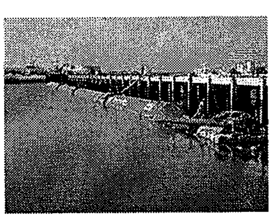
See also: Geothermal energy in the United States

The International Geothermal Association (IGA) has reported that 10,715 megawatts (MW) of geothermal power in 24 countries is online, which is expected to generate 67,246 GWh of electricity in 2010.[52] This represents a 20% increase in geothermal power online capacity since 2005. IGA projects this will grow to 18,500 MW by 2015, due to the large number of projects presently under consideration, often in areas previously assumed to have little exploitable resource.[52]

In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants;[53] the largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California.[54] The Philippines follows the US as the second highest producer of geothermal power in the world, with 1,904 MW of capacity online; geothermal power makes up approximately 18% of the country's electricity generation.[53]

Geothermal (ground source) heat pumps represented an estimated 30 GWth of installed capacity at the end of 2008, with other direct uses of geothermal heat (i.e., for space heating, agricultural drying and other uses) reaching an estimated 15 GWth. As of 2008, at least 76 countries use direct geothermal energy in some form.

Wave farms expansion



One of 3 Pelamis Wave Energy Converters in the harbor of Peniche,

Portugal
Main article: Wave farm

Portugal now has the world's first commercial wave farm, the *Agucadoura Wave Park*, officially opened in September 2008. The farm uses three Pelamis P-750 machines generating 2.25 MW.[55][56] Initial costs are put at € 8.5 million. A second phase of the project is now planned to increase the installed capacity to 21MW using a further 25 Pelamis machines.[57]

Funding for a wave farm in Scotland was announced in February, 2007 by the Scottish Government, at a cost of over 4 million pounds, as part of a UK£13 million funding packages for ocean power in Scotland. The farm will be the world's largest with a capacity of 3MW generated by four Pelamis machines.[58]

Developing country markets

Main article: Renewable energy in developing countries

Renewable energy can be particularly suitable for developing countries. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative.[59]

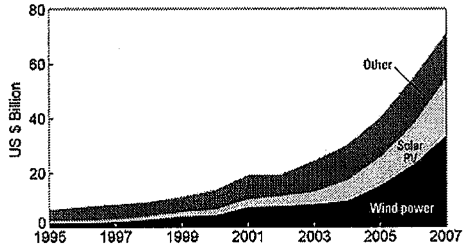
Biomass cookstoves are used by 40 percent of the world's population. These stoves are being manufactured in factories and workshops worldwide, and more than 160 million households now use them.[13] More than 30 million rural households get lighting and cooking from biogas made in household-scale digesters. An estimated 3 million households get power from small solar PV systems. Micro-hydro systems configured into village-scale or county-scale mini-grids serve many areas.[13]

Kenya is the world leader in the number of solar power systems installed per capita. More than 30,000 very small solar panels, each producing 12 to 30 watts, are sold in Kenya annually.[60]

Renewable energy projects in many developing countries have demonstrated that renewable energy can directly contribute to poverty alleviation by providing the energy needed for creating businesses and employment. Renewable energy technologies can also make indirect contributions to alleviating poverty by providing energy for cooking, space heating, and lighting. Renewable energy can also contribute to education, by providing electricity to schools.[61]

Industry and policy trends

See also: Renewable energy industry and Renewable energy policy



Global renewable energy investment growth (1995-2007)[62]

Global revenues for solar photovoltaics, wind power, and biofuels expanded from $76 billion in 2007 to $115 billion in 2008. New global investments in clean energy technologies expanded by 4.7 percent from $148 billion in 2007 to $155 billion in 2008.[15] U.S. President Barack Obama's American Recovery and Reinvestment Act of 2009 includes more than $70 billion in direct spending and tax credits for clean energy and associated transportation programs. Clean Edge suggests that the commercialization of clean energy will help countries around the world pull out of the current economic malaise.[15] Leading renewable energy companies include First Solar, Gamesa, GE Energy, Q-Cells, Sharp Solar, Siemens, SunOpta, Suntech, and Vestas.[63]

The International Renewable Energy Agency (IRENA) is an intergovernmental organization for promoting the adoption of renewable energy worldwide. It aims to provide concrete policy advice and facilitate capacity building and technology transfer. IRENA was formed on January 26, 2009, by 75 countries signing the charter of IRENA.[64] As of March 2010, IRENA has 143 member states who all are considered as founding members, of which 14 have also ratified the statute.[65]

Renewable energy policy targets exist in some 73 countries around the world, and public policies to promote renewable energy use have become more common in recent years. At least 64 countries have some type of policy to promote renewable power generation. Mandates for solar hot water in new construction are becoming more common at both national and local levels. Mandates for blending biofuels into vehicle fuels have been enacted in 17 countries.[66]

New and emerging renewable energy technologies

New and emerging renewable energy technologies are still under development and include cellulosic ethanol, hot-dry-rock geothermal power, and ocean energy.[67] These technologies are not yet widely demonstrated or have limited commercialization. Many are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and research, development and demonstration (RD&D) funding.[67]

Cellulosic ethanol

See also: Cellulosic ethanol commercialization

Companies such as Iogen, Broin, and Abengoa are building refineries that can process biomass and turn it into ethanol, while companies such as Diversa, Novozymes, and Dyadic are producing enzymes which could enable a cellulosic ethanol future. The shift from food crop feedstocks to waste residues and native grasses offers significant opportunities for a range of players, from farmers to biotechnology firms, and from project developers to investors.[68]

Selected Commercial Cellulosic Ethanol Plants in the U.S.[69][70]
(Operational or under construction)

Company	Location	Feedstock
Abengoa Bioenergy	Hugoton, KS	Wheat straw
BlueFire Ethanol	Irvine, CA	Multiple sources
Gulf Coast Energy	Mossy Head, FL	Wood waste
Mascoma	Lansing, MI	Wood
POET LLC	Emmetsburg, IA	Corn cobs
Range Fuels[71]	Treutlen County, GA	Wood waste
SunOpta	Little Falls, MN	Wood chips
Xethanol	Auburndale, FL	Citrus peels

Ocean energy

Systems to harvest utility-scale electrical power from ocean waves have recently been gaining momentum as a viable technology. The potential for this technology is considered promising, especially on west-facing coasts with latitudes between 40 and 60 degrees:[72]

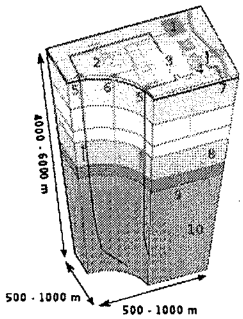
> In the United Kingdom, for example, the Carbon Trust recently estimated the extent of the economically viable offshore resource at 55 TWh per year, about 14% of current national demand. Across Europe, the technologically achievable resource has been estimated to be at least 280 TWh per year. In 2003, the U.S. Electric Power Research Institute (EPRI) estimated the viable resource in the United States at 255 TWh per year (6% of demand).[72]

The world's first commercial tidal power station was installed in 2007 in the narrows of Strangford Lough in Ireland. The 1.2 megawatt underwater tidal electricity generator, part of Northern Ireland's Environment & Renewable Energy Fund scheme, takes advantage of the fast tidal flow (up to 4 metres per second) in the lough. Although the generator is powerful enough to power a thousand homes, the turbine has minimal environmental impact, as it is almost entirely submerged, and the rotors pose no danger to wildlife as they turn quite slowly.[73]

Ocean thermal energy conversion (OTEC) uses the temperature difference that exists between deep and shallow waters to run a heat engine.

Enhanced Geothermal Systems

Main article: Enhanced Geothermal Systems



Enhanced geothermal system
1:Reservoir
2:Pump house
3:Heat exchanger
4:Turbine hall
5:Production well
6:Injection well
7:Hot water to district heating
8:Porous sediments
9:Observation well
10:Crystalline bedrock

Enhanced Geothermal Systems are a new type of geothermal power technologies that do not require natural convective hydrothermal resources. The vast majority of geothermal energy within drilling reach is in dry and non-porous rock.[74] EGS technologies "enhance" and/or create geothermal resources in this "hot dry rock (HDR)" through hydraulic stimulation.

EGS / HDR technologies, like hydrothermal geothermal, are expected to be baseload resources which produce power 24 hours a day like a fossil plant. Distinct from hydrothermal, HDR / EGS may be feasible anywhere in the world, depending on the economic limits of drill depth. Good locations are over deep granite covered by a thick (3–5 km) layer of insulating sediments which slow heat loss.[75] HDR wells are expected to have a useful life of 20 to 30 years before the outflow temperature drops about 10 degrees Celsius and the well becomes uneconomic. If left for 50 to 300 years the temperature will recover.[*citation needed*]

There are HDR and EGS systems currently being developed and tested in France, Australia, Japan, Germany, the U.S. and Switzerland. The largest EGS project in the world is a 25 megawatt demonstration plant currently being developed in the Cooper Basin, Australia. The Cooper Basin has the potential to generate 5,000–10,000 MW.

Nanotechnology thin-film solar panels

Solar power panels that use nanotechnology, which can create circuits out of individual silicon molecules, may cost half as much as traditional photovoltaic cells, according to executives and investors involved in developing the products. Nanosolar has secured more than $100 million from investors to build a factory for nanotechnology thin-film solar panels.

Other

Osmotic power (or *salinity gradient power*) is the energy retrieved from the difference in the salt concentration between seawater and river water. Two practical methods for this are reverse electrodialysis[76] (RED) and pressure retarded osmosis.[77] (PRO).

A microbial fuel cell is a bio-electrochemical system that drives a current by mimicking bacterial interactions found in nature - converting chemical energy to electrical energy by the catalytic reaction of microorganisms.

Renewable energy debate

Main article: Renewable energy debate

Renewable electricity production, from sources such as wind power and solar power, is sometimes criticized for being variable or intermittent. However, the International Energy Agency has stated that deployment of renewable technologies usually increases the diversity of electricity sources and, through local generation, contributes to the flexibility of the system and its resistance to central shocks.[67]

There have been "not in my back yard" (NIMBY) concerns relating to the visual and other impacts of some wind farms, with local residents sometimes fighting or blocking construction.[78] In the USA, the Massachusetts Cape Wind project was delayed for years partly because of aesthetic concerns. However, residents in other areas have been more positive and there are many examples of community wind farm developments. According to a town councilor, the overwhelming majority of locals believe that the Ardrossan Wind Farm in Scotland has enhanced the area.[79]

See also

- ***Renewable energy portal***
- ***Energy portal***
- ***Sustainable development portal***

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Books

- Alternative Energy: Political, Economic, and Social Feasibility
- The Clean Tech Revolution
- Energy and American Society: Thirteen Myths
- Energy Autonomy: The Economic, Social & Technological Case for Renewable Energy
- Greenhouse Solutions with Sustainable Energy
- Non-Nuclear Futures: The Case for an Ethical Energy Strategy
- Outlook On Renewable Energy In America
- Renewable Electricity and the Grid
- Renewable Energy Sources and Climate Change Mitigation
- Small is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size
- Solar Electricity Handbook
- Ten Technologies to Fix Energy and Climate

References

1. ^ *a* *b* *c* REN21 (2010). Renewables 2010 Global Status Report p. 15-16.
2. ^ REN21 (2008). Global Status Report 2007 REN21 Secretariat, 51 pages.
3. ^ *a* *b* Lars Kroldrup. Gains in Global Wind Capacity Reported *Green Inc.*, February 15, 2010.
4. ^ REN21 (2009). Renewables Global Status Report: 2009 Update p. 9.
5. ^ Global wind energy markets continue to boom – 2006 another record year (PDF).

6. ^ a b c James Russell. Record Growth in Photovoltaic Capacity and Momentum Builds for Concentrating Solar Power *Vital Signs*, June 03, 2010.
7. ^ a b REN21 (2009). Renewables Global Status Report: 2009 Update p. 12.
8. ^ REN21 (2009). Renewables Global Status Report: 2009 Update p. 15.
9. ^ World's largest photovoltaic power plants
10. ^ Solar Trough Power Plants (PDF).
11. ^ America and Brazil Intersect on Ethanol
12. ^ World Energy Assessment (2001). Renewable energy technologies, p. 221.
13. ^ a b c d REN21 (2010). Renewables 2010 Global Status Report p. 12.
14. ^ United Nations Environment Programme *Global Trends in Sustainable Energy Investment 2007: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency in OECD and Developing Countries* (PDF), p. 3.
15. ^ a b c Clean Edge (2009). Clean Energy Trends 2009 pp. 1-4.
16. ^ Renewables Global Status Report 2009 Update (PDF).
17. ^ Renewable energy... into the mainstream p. 9.
18. ^ a b c REN21 (2010). Renewables 2010 Global Status Report p. 15.
19. ^ a b c REN21 (2010). Renewables 2010 Global Status Report p. 53.
20. ^ EWEA Executive summary "Analysis of Wind Energy in the EU-25" (PDF). European Wind Energy Association. http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Summar EWEA Executive summary. Retrieved 2007-03-11.
21. ^ How Does A Wind Turbine's Energy Production Differ from Its Power Production?
22. ^ Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow? retrieved 24 January 2008.
23. ^ "*Offshore stations experience mean wind speeds at 80 m that are 90% greater than over land on average.* Evaluation of global wind power
"*Overall, the researchers calculated winds at 80 meters [300 feet] traveled over the ocean at approximately 8.6 meters per second and at nearly 4.5 meters per second over land [20 and 10 miles per hour, respectively].*" Global Wind Map Shows Best Wind Farm Locations (URL accessed January 30, 2006).
24. ^ Richard Shelquist (18 October 2005). "Density Altitude Calculator". http://wahiduddin.net/calc/calc_da_m.htm. Retrieved 2007-09-17.
25. ^ "Water Density Calculator". CSG, Computer Support Group, Inc. and CSGNetwork.Com. Copyright© 1973–2007. http://www.csgnetwork.com/h2odenscalc.html. Retrieved 2007-09-17.
26. ^ a b Union of Concerned Scientists. How Biomass Energy Works
27. ^ "Towards Sustainable Production and Use of Resources: Assessing Biofuels". United Nations Environment Programme. 2009-10-16.

http://www.unep.fr/scp/rpanel/pdf/Assessing_Biofuels_Full_Report.pdf. Retrieved 2009-10-24.

28. ^ REN21 (2010). Renewables 2010 Global Status Report p. 13.
29. ^ REN21 (2009). Renewables Global Status Report: 2009 Update p. 9.
30. ^ Eric Martinot and Janet Sawin. Renewables Global Status Report 2009 Update, *Renewable Energy World*, September 9, 2009.
31. ^ Renewable energy costs drop in '09 *Reuters*, November 23, 2009.
32. ^ Solar Power 50% Cheaper By Year End - Analysis *Reuters*, November 24, 2009.
33. ^ ***a*** ***b*** Al Gore (2009). *Our Choice*, Bloomsbury, p. 58.
34. ^ World Wind Energy Association (2008). Wind turbines generate more than 1 % of the global electricity
35. ^ New Report a Complete Analysis of the Global Offshore Wind Energy Industry and its Major Players
36. ^ U.S., China Lead Global Wind Installation
37. ^ E.ON wraps up 457 MW wind farm, transfers assets
38. ^ Blown away
39. ^ Global Concentrated Solar Power Industry to Reach 25 GW by 2020
40. ^ Solar Thermal Projects Under Review or Announced
41. ^ REN21 (2008). Renewables 2007 Global Status Report (PDF) p. 12.
42. ^ Solar Expected to Maintain its Status as the World's Fastest-Growing Energy Technology
43. ^ PV Resources.com (2009). World's largest photovoltaic power plants
44. ^ Strickland, Tonya (2008-04-24). "$1 billion-plus Carrisa Plains solar farm could power 190,000 firms". *The San Luis Obispo Tribune*. http://www.sanluisobispo.com/178/story/341999.html. Retrieved 2008-08-19.
45. ^ "PG&E Signs Historic 800 MW Photovoltaic Solar Power Agreements With Optisolar and Sunpower". Pacific Gas & Electric. 2008-08-14. http://www.pge.com/about/news/mediarelations/newsreleases/q3_2008/080814.shtml. Retrieved 2008-08-15.
46. ^ Solar Integrated in New Jersey.
47. ^ "Industry Statistics: Annual World Ethanol Production by Country". Renewable Fuels Association. http://www.ethanolrfa.org/industry/statistics/#E. Retrieved 2008-05-02.
48. ^ Macedo Isaias, M. Lima Verde Leal and J. Azevedo Ramos da Silva (2004). "Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil" (PDF). Secretariat of the Environment, Government of the State of São Paulo. http://www.eners.ch/plateforme/medias/macedo_2004.pdf. Retrieved 2008-05-09.
49. ^ Daniel Budny and Paulo Sotero, editor (2007-04). "Brazil Institute Special Report: The Global Dynamics of Biofuels" (PDF). Brazil Institute of the Woodrow Wilson Center.

http://www.wilsoncenter.org/topics/pubs/Brazil_SR_e3.pdf. Retrieved 2008-05-03.

50. ^ Erica Gies. As Ethanol Booms, Critics Warn of Environmental Effect *The New York Times*, June 24, 2010.
51. ^ *a* *b* "American Energy: The Renewable Path to Energy Security" (PDF). Worldwatch Institute. September 2006. http://images1.americanprogress.org/il80web20037/americanenergynow/AmericanEnergy.pdf. Retrieved 2007-03-11.
52. ^ *a* *b* Geothermal Energy Association. Geothermal Energy: International Market Update May 2010, p. 4-6.
53. ^ *a* *b* Geothermal Energy Association. Geothermal Energy: International Market Update May 2010, p. 7.
54. ^ Khan, M. Ali (2007). "The Geysers Geothermal Field, an Injection Success Story" (pdf). http://www.gwpc.org/meetings/forum/2007/proceedings/Papers/Khan,%20Ali%20Paper.pdf. Retrieved 2010-01-25
55. ^ Sea machine makes waves in Europe
56. ^ Wave energy contract goes abroad
57. ^ Joao Lima. "Babcock, EDP and Efacec to Collaborate on Wave Energy Projects". *Bloomberg Television*. http://www.bloomberg.com/apps/news?pid=20601081&sid=aSsaOB9qbiKE&refer=australia. Retrieved 2008-09-24.
58. ^ Orkney to get 'biggest' wave farm.
59. ^ Power for the People p. 3.
60. ^ The Rise of Renewable Energy
61. ^ Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals pp. 7-9.
62. ^ REN21 (2008) *Renewables 2007 Global Status Report* (Paris: REN21 Secretariat and Washington, DC:Worldwatch Institute).
63. ^ REN21 (2008). Renewables 2007 Global Status Report (PDF) p. 18.
64. ^ http://irena.org/downloads/Founconf/Signatory_States_20090126.pdf
65. ^ http://irena.org/downloads/Foundconf/Signatory_States_2010.pdf
66. ^ REN21 (2009). Renewables Global Status Report: 2009 Update p. 8.
67. ^ *a* *b* *c* International Energy Agency (2007). *Renewables in global energy supply: An IEA facts sheet* (PDF), OECD, p. 3.
68. ^ Pernick, Ron and Wilder, Clint (2007). *The Clean Tech Revolution* p. 96.
69. ^ Decker, Jeff. Going Against the Grain: Ethanol from Lignocellulosics, *Renewable Energy World*, January 22, 2009.
70. ^ Building Cellulose
71. ^ Range Fuels receives $80 million loan
72. ^ *a* *b* Jeff Scruggs and Paul Jacob. Harvesting Ocean Wave Energy, *Science*, Vol. 323, 27 February 2009, p. 1176.
73. ^ World tidal energy first for NI, BBC News *BBC News*, 7 June 2007.
74. ^ Duchane, Dave; Brown, Don (December 2002). "Hot Dry Rock (HDR) Geothermal Energy Research and Development at Fenton Hill, New Mexico". *Geo-Heat Centre Quarterly Bulletin* (Klamath Falls, Oregon: Oregon Institute of Technology) **23**

(4): pp. 13–19. ISSN 0276-1084. http://geoheat.oit.edu/bulletin/bull23-4/art4.pdf. Retrieved 2009-05-05
75. ^ 20 slide presentation inc geothermal maps of Australia
76. ^ Power generation by reverse electrodialysis
77. ^ How does PRO work?
78. ^ http://www.livescience.com/environment/080114-wind-energy.html
79. ^ Wind farms are not only beautiful, they're absolutely necessary

Bibliography

- Aitken, Donald W. (2010). *Transitioning to a Renewable Energy Future*, International Solar Energy Society, January, 54 pages.
- HM Treasury (2006). *Stern Review on the Economics of Climate Change*, 575 pages.
- International Council for Science (c2006). *Discussion Paper by the Scientific and Technological Community for the 14th session of the United Nations Commission on Sustainable Development*, 17 pages.
- International Energy Agency (2006). *World Energy Outlook 2006: Summary and Conclusions*, OECD, 11 pages.
- International Energy Agency (2007). *Renewables in global energy supply: An IEA facts sheet*, OECD, 34 pages.
- International Energy Agency (2008). *Deploying Renewables: Principles for Effective Policies*, OECD, 8 pages.
- Makower, Joel, and Ron Pernick and Clint Wilder (2009). *Clean Energy Trends 2009*, Clean Edge.
- National Renewable Energy Laboratory (2006). *Non-technical Barriers to Solar Energy Use: Review of Recent Literature*, Technical Report, NREL/TP-520-40116, September, 30 pages.
- REN21 (2008). *Renewables 2007 Global Status Report*, Paris: REN21 Secretariat, 51 pages.
- REN21 (2009). *Renewables Global Status Report: 2009 Update*, Paris: REN21 Secretariat.
- REN21 (2010). *Renewables 2010 Global Status Report*, Paris: REN21 Secretariat, 78 pages.
- United Nations Environment Programme and New Energy Finance Ltd. (2007). *Global Trends in Sustainable Energy Investment 2007: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency in OECD and Developing Countries*, 52 pages.
- Worldwatch Institute and Center for American Progress (2006). *American energy: The renewable path to energy security*, 40 pages.

v · d · e **Renewable energy by country (list of topics)** [show]

v · d · e **Topics related to environmental technology** [show]

v · d · e **Global warming and climate change** [show]

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Related topics:
- Acid Rain
- Air Pollution
- Conservation

Related answers:
- Is geothermal **energy** a **renewable energy**? *Read answer...*
- What energys are **renewable**? *Read answer...*
- An example of a **renewable energy** source? *Read answer...*

Help us answer these:
- How is **renewable energy renewable**?
- About **renewable** and non-**renewable energy**?
- Is **renewable energy** actually **renewable**?

EXHIBIT F

University of Missouri

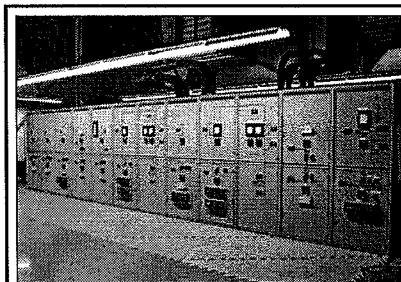
Campus Facilities
University of Missouri

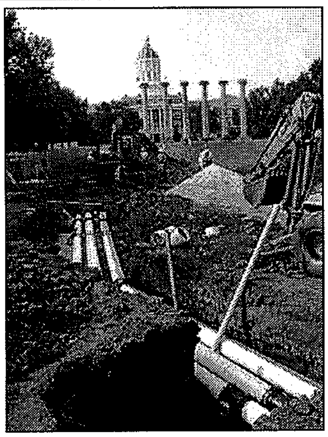
Utility Distribution

Campus Facilities – Energy Management's Utility Distribution unit is responsible for distributing electricity, steam, water and chilled water throughout the MU campus. This unit is comprised of three groups, **Electric Distribution, Steam & Water Distribution** and **Chilled Water Distribution.**

Electric Distribution

Electric Distribution is responsible for the distribution of electricity from the Power Plant or tie lines with the City of Columbia to all of the buildings on the MU Campus. Our personnel perform the operations, maintenance, engineering, new construction project coordination, system planning, system upgrades and metering for the high-voltage system on campus. Electric Distribution personnel operate and maintain six separate substations housing 96 line breakers and associated equipment. Over 60 miles of high-voltage lines run through underground duct banks to a network of switches and transformers. We have more than 338 building transformers and over 355 meters for monitoring electric usage.


Electric substation.


Water pipe installation on Francis Quadrangle.

Steam & Water Distribution

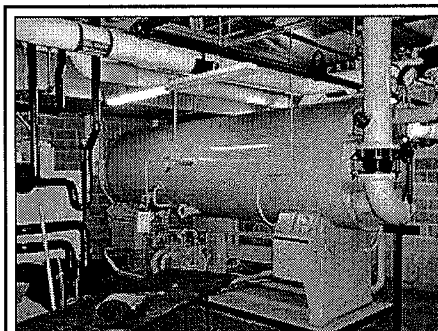
Steam and Water Distribution operates and maintains 26 miles of underground steam and condensate piping system providing thermal energy to campus. It is also responsible for maintaining the 23 miles of potable water distribution system on campus. In addition to its everyday uses, potable water is also used for fire protection. Over 2 million gallons of water is distributed throughout the campus every day — enough to fill Memorial Stadium to a depth of seven feet!

This group also maintains the underground chilled water piping used to network our building cooling systems. Together, these distribution systems comprise over 70 miles of underground utility piping.

Chilled Water Distribution

The District Cooling group is responsible for the operation and maintenance of chilled water systems on campus. Chilled water is used to provide air conditioning for most campus buildings. It is produced in machines called chillers and pumped through air-handlers in each building to cool the air. MU currently has approximately 24,000 tons of cooling capacity serving 8.5 million square feet of building space. Approximately half of the chiller capacity utilizes steam to produce chilled water. This is the same steam that has already been used in the power plant to produce electricity as part of the Combined Heat and Power process.

Strategically located throughout campus, satellite chilled water plants are connected together by 15.8 miles of underground piping which supply chilled water to over 100 campus buildings. All chiller systems are controlled and metered centrally by the EMCS. As building cooling demand fluctuates, the EMCS varies chiller production capacity — operating first the most efficient chillers in the chilled-water loop. Production costs are monitored and chiller performance is analyzed to ensure peak efficiency.


Steam Absorption Chiller.

Related Links

- Underground Locates
- Electric Distribution Animation
- Steam Distribution Animation
- Steam Absorption Chiller Animation

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